Mercury problems and alternatives

Mercury problem

Mercury is a naturally occurring substance that can cause serious health and ecological problems when released to the environment through human activities. It rarely occurs free in nature and is found mainly in cinnabar ore (HgS) in Spain and Italy. It is used in thermometers, dental amalgams. Mercury concentrations in air are usually low and of little direct concern. But when mercury enters water, biological processes transform it to a highly toxic form that builds up in fish and animals that eat fish. People are exposed to mercury primarily by eating fish.

Mercury is poisonous as mercury vapour permeates through the respiratory track and the skin. Swallowed liquid mercury is not absorbed out of the stomach, and usually passes out of the body without harm. Some organic and inorganic mercury compounds can also be inhaled and absorbed through the lungs, and may pass through the skin, but the compounds can also be absorbed through the stomach if swallowed, and many compounds are irritating or corrosive to the skin, eyes and mucus membranes as well. The Threshold Limit Value (TLV) for mercury is 0.05 mg/m³ of air.

Symptoms usually begin with cough, chest tightness, trouble breathing, upset stomach and nervous disorder. This may go on to irreversible pneumonia. If some mercury compounds are swallowed, nausea, vomiting diarrhoea and severe kidney damage can occur.

Mercury thermometer

Mercury is used in thermometers because of its wide liquid range (234..630 K), in spite of its low thermal expansion coefficient (eight times less than alcohol). Additional advantages are its high thermal conductivity, low thermal capacity, low vapour pressure, good visibility, and non-wetting of internal capillary walls.
Thermometers with a constriction, as clinical thermometers (Fig. 1), must be “shaken down before use” to function properly, creating a constant high potential for breakage.

When liquid mercury is spilled, it forms droplets that can accumulate in the tiniest of spaces and then emit vapours into the air. All mercury spills, regardless of quantity, should be treated seriously.

**Mercury barometers**

The first (1643) and most common barometer is the Torricelli type (Fig. 2), where mercury in an inverted long tube is not let to fall into an open mercury bath by the pressure of atmospheric air (around 760 mm-Hg at sea level. The key advantage of mercury is its great density (a water column of 10 m would be required instead of the 0.76 m Hg column). The standard atmosphere (sea-level pressure) was establish by assuming a perfect 760 mm column at 0 ºC, under $g=9.80665$ m/s$^2$, made of pure mercury with $\rho=13595.1$ kg/m$^3$.

**Mercury cleaning procedures**

Cleanup procedures in the case of mercury spills (1..5 g in thermometers, 10..100 g in barometers):

1. Limit the spill (do not blow or aspir, join droplets).
2. Carefully pick up and place any broken pieces of glass (from the thermometer or any other containers) in a paper towel and place the towel in a sealable plastic bag to be discarded.
3. Collect droplets on a soft paper or tissue (pushing the droplets with a piece of paper), to be discarded in the trash enclosed in a bag.
4. Soft materials contaminated with mercury should be discarded, but hard surfaces can be cleaned by just getting rid of droplets and washing.
5. Beware of jewellery; mercury adheres to gold very easily.
Galinstan metal alloy and other liquid metals

Galinstan is a silvery liquid eutectic mixture of gallium, indium and tin, made by Geratherm. It has a melting point of \( T_m = -20 \, ^\circ C \), \( T_b > 1300 \, ^\circ C \), \( \rho = 6440 \, \text{kg/m}^3 \), sound speed 2950 m/s, viscosity 0.0024 Pa∙s at 20 °C. They are much more viscous than Hg. In 2003, \( 1/4 \) of silvery thermometers use galinstan instead of mercury.

Any alloy containing gallium in a concentration of 65-95 wt.-%, indium in a concentration of 5-22 wt.-% and tin in a concentration of 0-11 wt.-%, can be used for thermometers, but ample margin must be allowed to avoid shatter by freezing; e.g. \( T_m < -10 \, ^\circ C \).

There can be other liquid metals at room temperature, as Na-K 22/78%wt eutectic alloy, with \( T_m = -12.6 \, ^\circ C \), \( T_b = 785 \, ^\circ C \), \( \rho_L = 866 \, \text{kg/m}^3 \) at 20 °C (at 100 °C, \( \rho_L = 855 \, \text{kg/m}^3 \), \( \alpha_L = 340 \times 10^{-6} \, 1/K \), \( c_L = 936 \, \text{J/(kg\cdot K)} \), \( k_L = 23 \, \text{W/(m\cdot K)} \), \( \mu_L = 505 \times 10^{-6} \, \text{Pa\cdot s} \), \( \sigma_L = 115 \times 10^{-3} \, \text{N/m} \) and \( \sigma_{\text{ele}} = 2.5 \times 10^6 \, \text{S/m} \), i.e. 4% that of Cu). It is used for high-temperature heat-transfer fluid, catalyst, reagent in petrochemical processing, electrically-activated hydraulic fluid. It is a silver-coloured liquid metal, odourless and corrosive. It reacts violently with water, liberating and igniting flammable hydrogen gas, perhaps explosively. After exposure to air, may form yellow potassium superoxide which reacts violently and explosively with organics. It must be stored in a dry N₂ or Ar atmosphere, or better under oil.

Non-metal liquid thermometers (spirit thermometers)

There are several kinds of non-mercury thermometers, but their usefulness is limited by the temperature range allowed, i.e. it should not freeze or vaporise at normal temperatures (−10 °C..110 °C). Possible working liquids are:

- Red-dyed: alcohol, toluene, pentane, xylene, kerosene (some 1 g of liquid plus <0.03 g of aniline dye).
- Blue-dyed: isoamyl benzoate (pale-yellow, \( C_{12}H_{16}O_2 \), \( M = 0.192 \, \text{kg/mol} \), \( \rho = 990 \, \text{kg/m}^3 \), \( T_m = ?? \), \( T_b = 261 \, ^\circ C \), \( T_{\text{flash}} = 95 \, ^\circ C \), biodegradable).
- Dark-green-dyed: monoazo-anthroquinone dissolved in some natural oil and dyed.

Occasionally, the fluid in spirit thermometers will separate during storage and/or shipping, but this is a correctable problem. The two methods described below can be used. Remember to wear hand and eye protection when you perform either of these correction procedures.

- Heating Method: Holding the thermometer in an upright position and away from your face, heat it suspended in warming liquid or in hot air from a hair dryer (never from a flame!) just until the separated portion of the column enters the expansion chamber at the top of the thermometer (some 130 °C). Be very careful and stop heating as soon as the fluid enters the expansion chambers. Over-filling the expansion chamber will break the thermometer. Now, while keeping the thermometer in an upright position, tap it gently against the surface of a rubber stopper. This should allow the gas separating the column to rise above the column. Allow the thermometer to cool slowly and store it in an upright position.
- Cooling Method: Keeping the thermometer upright, place only the thermometer bulb in a solution of shaved ice and salt or dry ice and alcohol. Allow the liquid column to retreat into the
bulb, and then swing the thermometer in an arc. This should release the trapped gas and permit it to escape above the column. Allow the thermometer to slowly return to room temperature and store it in an upright position.

Non-metal-filled thermometers have a response time 3 or 4 times larger than metal ones.

**Non-mercury clinic thermometers**

**ELECTRICAL THERMOMETERS**

Electrical (or digital) thermometers are based on variation of electrical resistance with temperature. They run on small batteries, take readings in less than a minute, beep when finished, displaying the results on a screen, and are as accurate as mercury thermometers.

![Fig. 3. Digital clinic thermometer.](image)

**INFRARED THERMOMETERS**

Infrared (or ear, or tympanic) thermometers are the easier to use, and give the result in just one second (compare with the five-to-ten minutes of the Hg thermometer!). Correct aiming of the ear probe and proper placement in the ear canal are important for accurate measurements.

![Fig. 4. Ear thermometer.](image)

There are additional solutions for clinic thermometry, like forehead thermometric strips, but they are usually less convenient.

*(Back to Laboratory)*